**Chapter 24 Section 2 Tools of Astronomy**

**Key Concepts**

How does a refracting telescope produce an image?

Why are most large telescopes reflecting telescopes?

How does a radio telescope gather data?

What advantages do space telescopes have over Earth-based telescopes?

**Vocabulary**

aberration

reflecting telescope

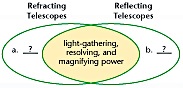
radio telescope

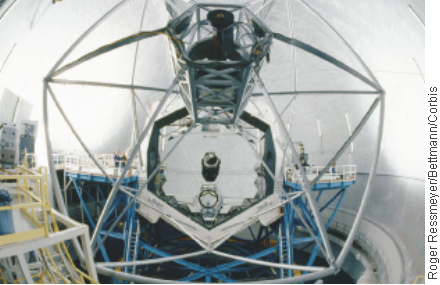
refracting

telescope

chromatic

**Reading Strategy**

**Comparing and Contrasting** Copy the Venn diagram. As you read, complete it to show the differences between refracting and reflecting telescopes.

Now that we’ve examined the nature of light, let’s turn our attention to the tools astronomers use to intercept and study the energy emitted by distant objects in the universe. Because the basic principles of detecting radiation were originally developed through visual observations, the astronomical tools we’ll explore first will be optical telescopes. An example is shown in Figure 5. The 10-meter Keck Telescope, located on Mauna Kea in Hawaii, uses a mosaic of 36 six-sided, 1.8- meter mirrors. The mirrors are carefully positioned by a computer to give the optical effect of a 10-meter mirror. The Keck Telescope is a type of optical telescope. To create an image that is a great distance away, a telescope must telescope. To create an image that is a great distance away, a telescope must collect as much light as possible. Optical telescopes contain mirrors, lenses, or both to accomplish this task.

**Figure 5 Keck Telescope** *This optical telescope is located at the summit of Hawaii’s Mauna Kea volcano.*

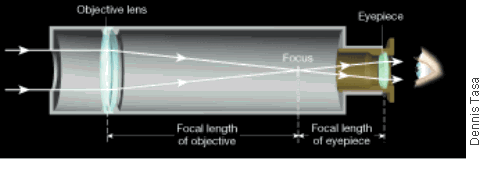
**Refracting Telescopes**

Galileo is considered to be the first person to have used telescopes for astronomical observations. Having learned about the newly invented instrument, Galileo built one of his own that was capable of magnifying objects 30 times. Because this early instrument, as well as its modern counterparts, used a lens to bend or refract light, it is known as a **refracting telescope**.

**Focus**

**The most important lens in a refracting telescope, the objective lens, produces an image by bending light from a distant object so that the light converges at an area called the focus (***focus* **= central point).** For an object such as a star, the image appears as a point of light. For nearby objects it appears as an inverted replica of the original.

You can easily demonstrate the latter case by holding a lens in one hand and, with the other hand, placing a white card behind the lens. Now vary the distance between them until an image appears on the card. The distance between the focus (where the image appears) and the lens is called the focal length of the lens.

Astronomers usually study an image from a telescope by first photographing the image. However, if a telescope is used to examine an image directly, a second lens, called an eyepiece, is required. The eyepiece magnifies the image produced by the objective lens. In this respect, it is similar to a magnifying glass. The objective lens produces a very small, bright image of an object, and the eyepiece enlarges the image so that details can be seen. Figure 6 shows the parts of a refracting telescope.

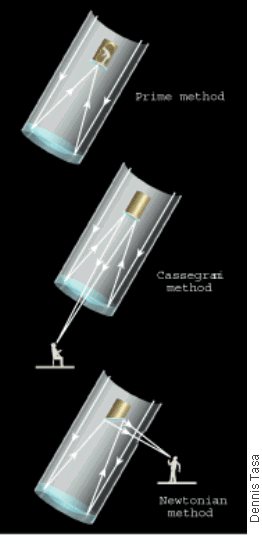
**Figure 6 Simple Refracting Telescope** *A refracting telescope uses a lens to bend light.*

**Chromatic Aberration**

Although used extensively in the nineteenth century, refracting telescopes suffer a major optical defect. As light passes through any lens, the shorter wavelengths of light are bent more than the longer wavelengths. Consequently, when a refracting telescope is in focus for red light, blue and violet light are out of focus. The troublesome effect, known as **chromatic (***chroma* **= color) aberration (***aberrare* **= to go astray)**, weakens the image and produces a halo of color around it. When blue light is in focus, a reddish halo appears. When red light is in focus, a bluish halo appears. Although this effect cannot be eliminated completely, it is reduced by using a second lens made of a different type of glass.

|  |
| --- |
| **Reading Checkpoint** |
| (a) What is chromatic aberration? |

**Reflecting Telescopes**

Newton was bothered by chromatic aberration so he built telescopes that reflected light from a shiny surface—a mirror. Because reflected light is not dispersed into its component colors, the chromatic aberration is avoided. **Reflecting telescopes** use a concave mirror that focuses the light in front of a mirror, rather than behind it, like a lens. The mirror is generally made of glass that is finely ground and coated with a highly reflective material, usually an aluminum compound.

Because the focus of a reflecting telescope is in front of the mirror, an observer must be able to view the image without blocking too much incoming light. Figure 7A shows a viewing cage for the observer within the telescope. Figures 7B and 7C show that the observer can remain indoors. Most large telescopes employ more than one type.

**Figure 7 Viewing Methods with Reflecting Telescopes A** *The prime method is only used with very large telescopes.* **B** *The Cassegrain method is most commonly used. Note that a small hole in the center of the mirror allows light to pass through.* **C** *This figure shows the Newtonian method.*

**Advantages of Reflecting Telescopes**

As you might guess, it’s a huge task to produce a large piece of high-quality, bubble-free glass for refracting telescopes. **Most large optical telescopes are reflectors. Light does not pass through a mirror so the glass for a reflecting telescope does not have to be of optical quality.** In addition, a lens can be supported only around the edge, so it sags. Mirrors, on the other hand, can be supported fully from behind. One disadvantage of reflecting telescopes is that the secondary mirror blocks some light entering the telescope. Thus, a reflecting telescope with a 10-inch opening will not collect as much light as a 10-inch refractor.

**Properties of Optical Telescopes**

Both refracting and reflecting telescopes have three properties that aid astronomers in their work: 1) light-gathering power, 2) resolving power, and 3) magnifying power. Light-gathering power refers to the telescope’s ability to intercept more light from distant objects, thereby producing brighter images. Telescopes with large lenses or mirrors “see” farther into space than do those with small ones.

Another advantage of telescopes with large objectives is their greater resolving power, which allows for sharper images and finer detail. For example, with the naked eye, the Milky Way appears as a vague band of light in the night sky. But even a small telescope is capable of resolving, or separating it into, individual stars. Lastly, telescopes have magnifying power, which is the ability to make an object larger. *Magnification is calculated by dividing the focal length of the objective by the focal length of the eyepiece.* Thus, the magnification of a telescope can be changed by simply changing the eyepiece.

|  |
| --- |
| **Reading Checkpoint** |
| (a)What is light-gathering power? |

**Detecting Invisible Radiation**

As you learned earlier, sunlight is made up of more than just the radiation that is visible to our eyes. Gamma rays, X-rays, ultraviolet radiation, infrared radiation, and radio waves are also produced by stars. Photographic film that is sensitive to ultraviolet and infrared radiation has been developed. This extends the limits of our vision. However, most of this radiation cannot penetrate our atmosphere, so balloons, rockets, and satellites must transport cameras “above” the atmosphere to record it.

A narrow band of radio waves is able to penetrate the atmosphere. Measurement of this radiation is important because we can map the galactic distribution of hydrogen. Hydrogen is the main material from which stars are made.

**Radio Telescopes**

The detection of radio waves is accomplished by big dishes called **radio telescopes**, shown in Figure 8A. In principle, the dish of one of these telescopes operates in the same manner as the mirror of an optical telescope. **A radio telescope focuses the incoming radio waves on an antenna, which absorbs and transmits these waves to an amplifier, just like a radio antenna.**

**Figure 8 A The 43-meter Radio Telescope at Green Bank, West Virginia** *The dish acts like the mirror of a reflecting telescope, focusing radio waves onto the antenna*. **B The Very Large Array Near Socorro, New Mexico** *Twenty-seven identical antennas operate together to form this radio network.* **Identifying** What is a network of radio telescopes called?

Because radio waves are about 100,000 times longer than visible radiation, the surface of the dish doesn’t need to be as smooth as a mirror. Except for the shortest radio waves, a wire mesh is a good reflector. However, because radio signals from celestial sources are very weak, large dishes are necessary to intercept an adequate signal.

Radio telescopes have poor resolution, making it difficult to pinpoint the radio source. Pairs or groups of telescopes reduce this problem. When several radio telescopes are wired together, as shown in Figure 8B, the resulting network is called a radio interferometer.

**Advantages of Radio Telescopes**

Radio telescopes have some advantages over optical telescopes. They are much less affected by turbulence in the atmosphere, clouds, and the weather. No protective dome is required, which reduces the cost of construction. “Viewing” is possible 24 hours a day. More important, radio telescopes can “see” through interstellar dust clouds that obscure visible wavelengths. Radio signals from distant points in the universe pass unhindered through the dust, giving us an unobstructed view. Furthermore, radio telescopes can detect clouds of gases too cool to emit visible light. These cold gas clouds are important because they are the sites of star formation.

|  |
| --- |
| **Question & Answer** |
| **Q** Why do astronomers build observatories on mountaintops?  **A** Observatories are most often located on mountaintops because sites above the densest part of the atmosphere provide better conditions for “seeing.” |

Radio telescopes are, however, hindered by human-made radio interference. While optical telescopes are placed on remote mountaintops to reduce While optical telescopes are placed on remote mountaintops to reduce interference from city lights, radio telescopes are often hidden in valleys to block human-made radio interference. Radio telescopes have revealed such spectacular events as the collision of two galaxies. They led to the important discovery of quasars and pulsars.

|  |
| --- |
| **Reading Checkpoint** |
| (a)Why can radio telescopes be used 24 hours a day? |

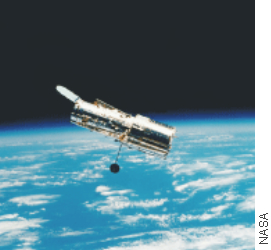
**Space Telescopes**

Have you ever seen a blurring effect caused by the movement of air on a hot summer day? That blurring effect also distorts the images produced by most telescopes on Earth. On a night when the stars twinkle, viewing is difficult because the air is moving rapidly. This causes the image to move about and blur.

Observatories are most often located on mountaintops. This is because sites above the densest part of the atmosphere provide better conditions for “seeing.” At high elevations, there is less air to scatter and dim the incoming light. Also, there is less water vapor to absorb infrared radiation. Further, the thin air on mountaintops causes less distortion of the images being observed.

There is one other way to get around the distorting effects of Earth’s atmosphere—send telescopes into space. **Space telescopes orbit above Earth’s atmosphere and thus produce clearer images than Earth-based telescopes.**

**Hubble Space Telescope**

The first space telescope, built by NASA, was the Hubble Space Telescope, shown in Figure 9. Hubble was put into orbit around Earth in April 1990. This 2.4-meter space telescope has 10 billion times more light-gathering power than the human eye. Hubble has given us many spectacular images. For example, the Hubble Space Telescope has provided images that clearly resolve the separation between Pluto and its moon, Charon. It has also provided data about planets that orbit other stars, the birth of stars, black holes, the age of the universe, and the expansion of the universe. **Figure 9 Hubble Space Telescope** *Hubble was deployed into Earth orbit by the space shuttle Discovery.*

**Other Space Telescopes**

Other types of radiation are also affected by Earth’s atmosphere. To study X- rays, NASA uses the Chandra X-Ray Observatory. This space telescope was launched in 1999. One of its main missions is to gather data about black holes —objects whose gravity is so strong that visible light cannot escape them. Another space telescope, the Compton Gamma-Ray Observatory, was used to study both visible light and gamma rays. In 2011, NASA plans to launch the James Webb Space Telescope to study infrared radiation. As Figure 10 shows, images obtained by different telescopes offer different information about the same object in space—in this case, the Milky Way galaxy. By studying all the images together, astronomers obtain a more thorough understanding of the galaxy.

**Figure 10 Images of the Milky Way Galaxy** *These images were taken by different types of telescopes, including visible light, X-ray, gamma ray, and infrared.*

**Chapter 24 SECTION 2 Tools of Astronomy Assessment**

**Reviewing Concepts**

(1) How does a refracting telescope work?

(2) How does a reflecting telescope **differ** from a refracting telescope?

(3) Why are most large telescopes reflecting telescopes?

(4) How do radio telescopes gather data?

(5) Why do space telescopes obtain clearer images than Earth-based telescopes?

**Critical Thinking**

(6) **Calculating** If a telescope has an objective with a focal length of 50 centimeters and an eyepiece with a focal length of 25 millimeter, what will be the magnification?

(7) **Applying Concepts** Using the numbers from the previous question, would an eyepiece with a greater focal length increase or decrease magnification? Explain.

**Chapter 24 SECTION 2 Tools of Astronomy Assessment**

**Reviewing Concepts**

(1) How does a refracting telescope work?

(2) How does a reflecting telescope **differ** from a refracting telescope?

(3) Why are most large telescopes reflecting telescopes?

(4) How do radio telescopes gather data?

(5) Why do space telescopes obtain clearer images than Earth-based telescopes?

**Critical Thinking**

(6) **Calculating** If a telescope has an objective with a focal length of 50 centimeters and an eyepiece with a focal length of 25 millimeter, what will be the magnification?

(7) **Applying Concepts** Using the numbers from the previous question, would an eyepiece with a greater focal length increase or decrease magnification? Explain.